1 up

NASA TT F-14,165

NASA TECHNICAL TRANSLATION

MEDICAL AND BIOLOGICAL PROBLEMS IN THE CONQUEST OF SPACE

V. V. Parin

Translation of "Mediko-Biologicheskiye Problemy Osvoyeniya Kosmosa," Zemlya i Vselennaya, No.3, 1970, pp. 15-23.

Moscow

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 FEBRUARY 1972

MEDICAL AND BIOLOGICAL PROBLEMS IN THE CONQUEST OF SPACE

V. V. Parin

ABSTRACT. The conquest of space and the planets of the Solar System involves the solution of complex biological and medico-technical problems. It is precisely on the manner in which these problems are solved that the further penetration of man into space depends.

The Birth of Space Medicine /15*

The past ten years have been filled with outstanding achievements in the field of space exploration. The regular launching of satellites for the study of space at various distances from Earth, sending automatic stations to the Moon and the nearby planets of the Solar System, the flights of manned spacecraft and biological satellites - all of these have become a frequent occurrence for the Soviet people.

In looking back, we can proudly state that the launching of the world's first artificial earth satellite by the USSR on 4 October 1957 marked the beginning of the space age, the start of the direct investigation of the Universe by man. It was no surprise that the Congress of the International Astronautical Federation, meeting in Belgrade in September 1957, officially agreed to consider this date as the start of the space age in the history of mankind.

Problems of ensuring human survival in a highly rarefied atmosphere and at low temperatures began to be solved in the 1930's, when high-altitude

---

* Numbers in the margin indicate the pagination in the original foreign text.

flights and the conquest of the stratosphere started their development.

In conjunction with the flights of the stratospheric balloons "USSR-1" and "Osoaviakhim-1" in 1933 and 1934, Soviet physiologists headed by L. A. Orbeli were faced with the problem of ensuring the survival and working ability of three fliers in hermetically sealed gondolas approximately 2 meters in diameter.

Subsequently the course of physiological processes in a hermetically sealed area was studied with a pressure of the artificial atmosphere on the order of 500 mm. The investigators succeeded in establishing the characteristics of the increase in the carbon dioxide concentration and the decrease in the oxygen content in the air inside the gondolas, finding ways to remove excess carbon dioxide and moisture from the air, recommending the most reliable and economical means of replacing the consumed oxygen, developing a food ration, emergency food supplies, and solving the problem of deviations in the vital activity of the "stratonauts."

The results obtained in solving these problems were later used in the design of hermetically sealed aircraft cabins and served as the basis for the development of life-support systems for spacecraft.

July, 1936, marked the start of the summer tests of the first experimental stratospheric aircraft, the BOK-1. The fuselage contained a cylindrical, hermetically sealed cabin with three windows in the forward section. This aircraft climbed to an altitude of more than 14 kilometers.

As a safety measure in the event of emergency depressurization of the cabins of stratospheric aircraft and to prevent explosive decompression, /16
Soviet engineers and aviation physicians devised the first pressure suits in 1940: the GVF suit designed by Pereskokov and Rappoport, the TsAGI suit designed by Khromushkin and Boyko, and the Ch-3 suit designed by Chertovskiy. Oxygen pressure could be maintained at 110-260 mm in these suits, and it was quite easy to move about in them.

The 1930's were generally characterized by the development of aviation medicine in the USSR. Equivalents of "infinite altitude"[(1)] began to be involved in the studies performed by aviation physiologists.

The work of Soviet physiologists and biochemists began to play an important role in the discovery of the mechanism regulating functions when the organism was subjected to the effects of oxygen insufficiency, accelerations, elevated and reduced barometric pressure, explosive decompression, high and low temperatures, low brightness levels, ultrahigh frequency electromagnetic oscillations, ultraviolet and infrared radiation, etc.

The results of the elaborate high-altitude expeditions on Mts. Altay, Pamir, Kazbek and El'brus which were conducted systematically after 1926 provided an idea of how altitude affects the organism after various periods of time, as well as the physiological and biochemical mechanisms of adaptation to it.

The establishment of the foundations of space medicine was also promoted by the theoretical and practical principles of surgical expertise for the flight crew, worked out in the 1920's and 40's. The status of Soviet aviation medicine was subjected to a severe test during World War II.

Early steps such as these, culminating at the end of the 1940's when the first vertical launchings of animals aboard geophysical rockets to altitudes above 100 km took place, made it possible to begin the preparations for sending man into space.

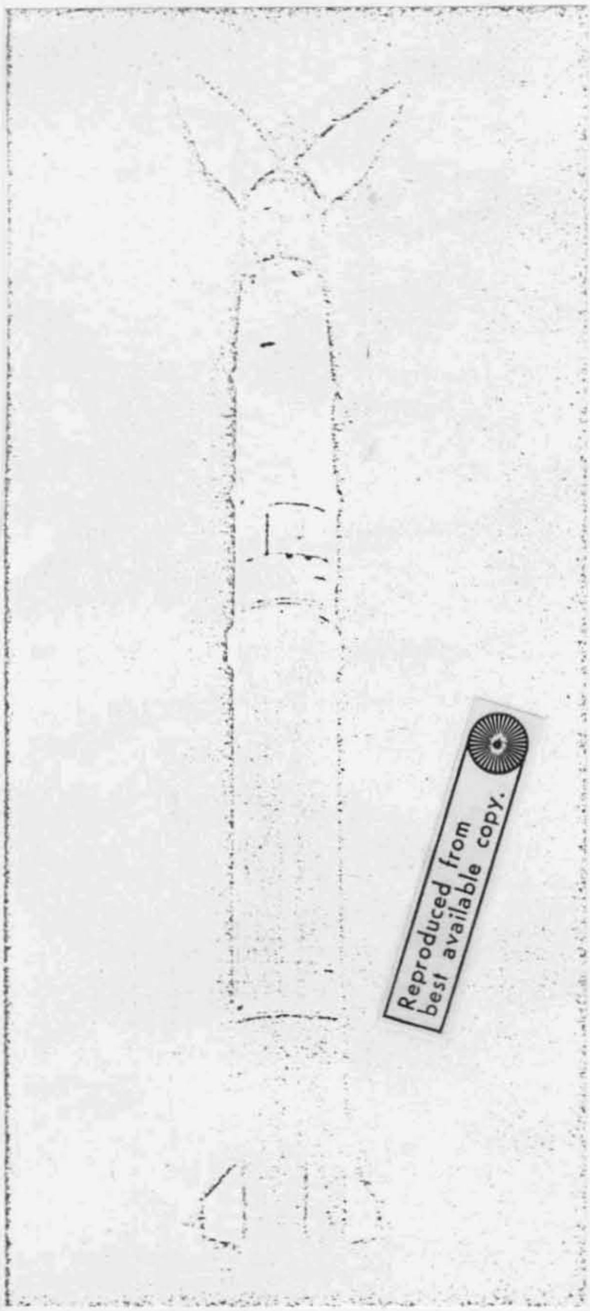
Biology and Medicine In the Service of the Conquerors of Space

The crucial event which marked the development of space biology and medicine into independent scientific disciplines was the successful accomplishment in the USSR of a program of biological studies carried out with high-

---

(1) "Infinite altitude" is the altitude beyond whose limits it is necessary to use insulating pressure suits (space suits) or regenerative-type hermetically sealed cabins.

altitude geophysical rockets, "Sputnik-2", and the spacecraft-satellites "KKS-2" and "KKS-5" (N. M. Sisakyan, O. G. Gazenko, V. V. Parin et al).

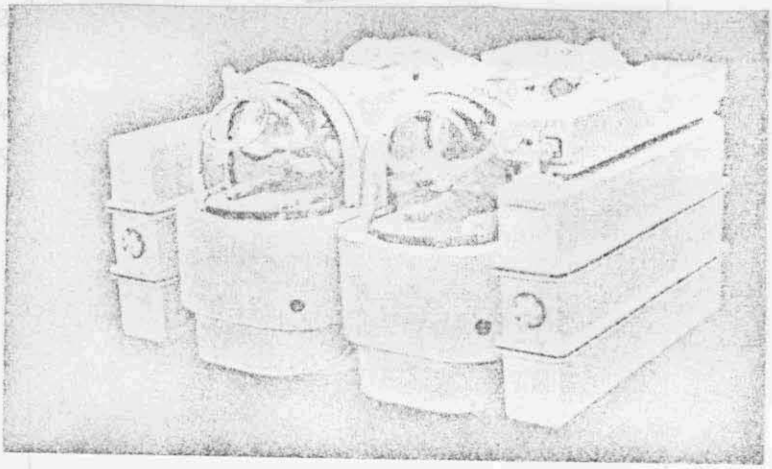


V5V Geophysical Rocket, Used to Develop Methods of Launching Animals Into Space and Retrieving Them.

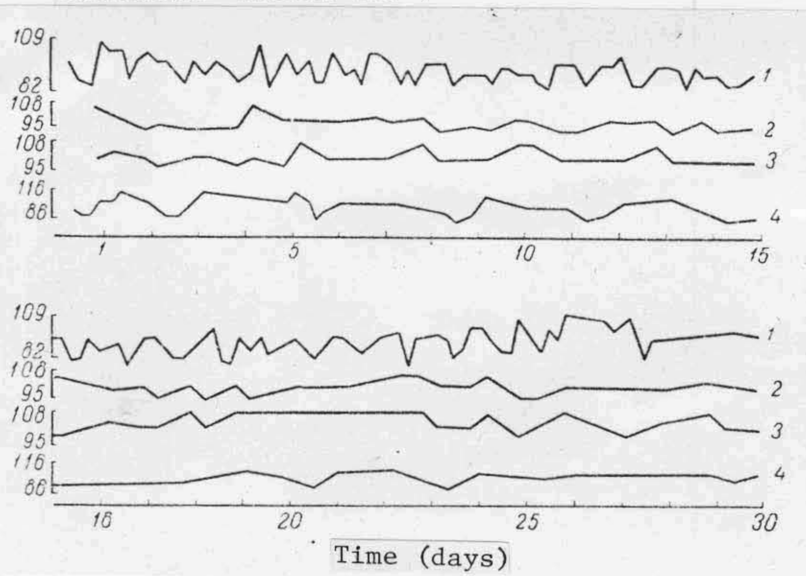
The goals of the work performed during the vertical flights of animals /17 (dogs and rabbits) aboard geophysical rockets equipped with pressurized cabins were first presented by A. V. Pokrovskiy at the International Astronautical Congress in Paris (3-8 December 1956). Rocket biological experiments involving flights to altitudes of 100, 200 and 450 km made it possible to solve many medical and biological problems associated with the penetration of man into outer space.

Science now has at its disposal data collected as the result of the 14-day stay of men in a state of weightlessness (this was the exact duration of the flight of the "Gemini-7" spacecraft) and the 22-day "space race" of the dogs aboard the Soviet spacecraft-satellite "Kosmos-110".

The flight of the "Apollo 11" spacecraft and especially the landing of the astronauts on the surface of the Moon was an important stage in the development of astronautics. This historic event will undoubtedly take its deserved place among the achievements of civilization, especially those such as



Cabin for Dogs Aboard the Soviet Spacecraft-Satellite "Kosmos-110".

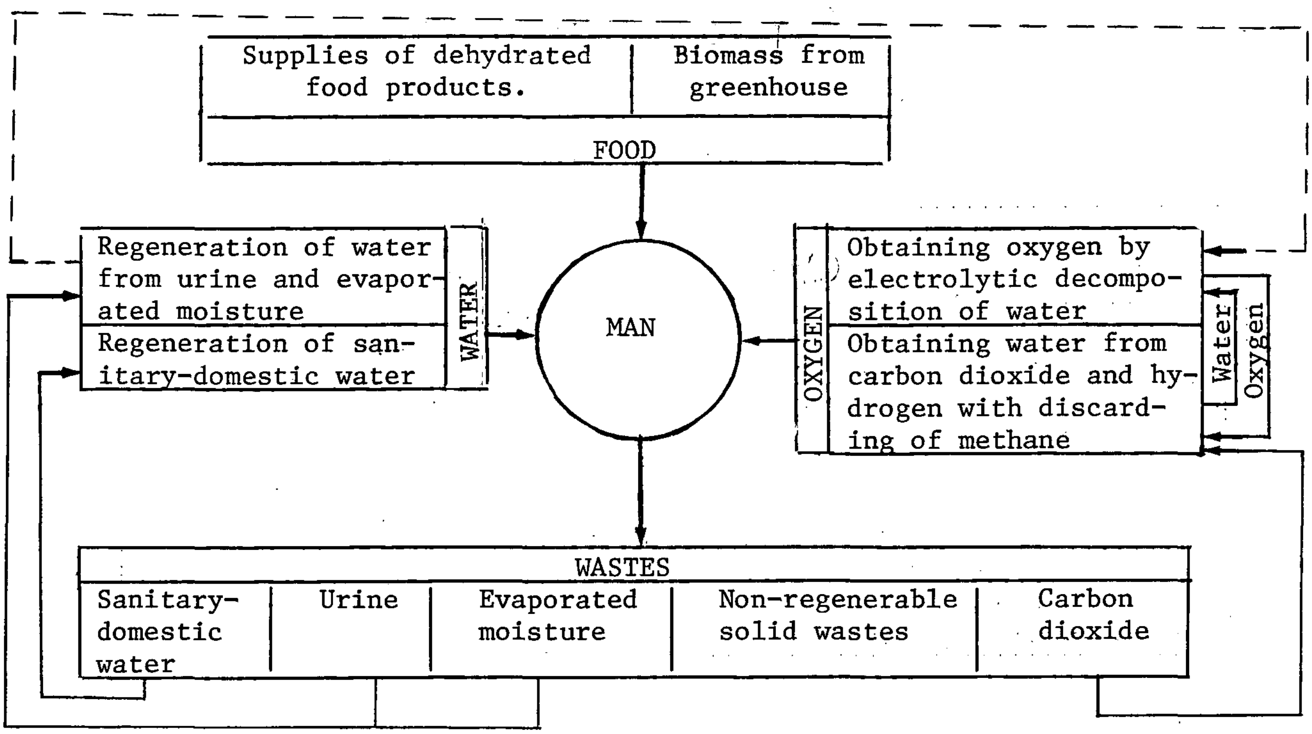


Dynamics of Physiological-Hygienic Parameters of Subjects During a 30-day Experiment: 1. Pulse Rate; 2 - Maximum Arterial Pressure; 3 - Minimum Arterial Pressure; 4 - Respiration Rate. No Symptoms of Toxicity Appeared During Continuous (up to 30 Days) Gaseous Contact of Man with Microscopic Algae.

the first space flight by Yuriy Gagarin and the first spacewalk by Aleksey Leonov. From the medical and biological standpoint, this experi- /18 ment serves the goal of developing solutions to problems of carrying out comparatively short-term manned flights, and places the direct conquest of the Moon on the agenda, together with the construction of semi-permanent scientific laboratories on its surface.

A possibility now opens up of evaluating on a practical level the living conditions for man, the details of his transportation, and checking the effectiveness of the supplies and equipment that have been devised. All of this is highly important for the subsequent improvement of methods by which man can conquer the Moon. We can also suggest that studies will be stimulated that are directed at problems of providing more permanent human habitation on the Moon, including the construction of scientific stations and settlements on its surface, such as Konstantin Eduardovich Tsiolkovskiy dreamed of and wrote about in his day.

Long-term residence of man on the Moon may be ensured by transporting and storing the required supplies of oxygen and provisions. This is an admittedly expensive, but nevertheless realistic, way of solving the problem.



Block Diagram of Metabolism in Ground Facility for Testing Life-Support Systems. This Complex Makes it Possible to Achieve Partially Closed Circulation of Substances.

In addition, it is quite likely that life-support systems can be used on the Moon which are based on principles of regeneration and recovery of products required by man: oxygen, water, etc.

With respect to designing possible life-support systems, tangible results have already been achieved in studies on supplying man with oxygen by means of plants (L. V. Kirenskiy, I. I. Gitel'zon et al.). Scientists place great hopes on microscopic algae, using them as gas exchangers for spacecraft. The problem of the "man-microscopic algae" system has been solved more successfully by Soviet scientists than abroad. In addition, almost all American scientists have stopped working on this problem, considering it economically and technologically inefficient.

In 1967 the results were published from a study of the continuous cultivation of microscopic algae (Chlorella) with a productivity of up to 100 liters of oxygen per square meter of illuminated reactor surface.

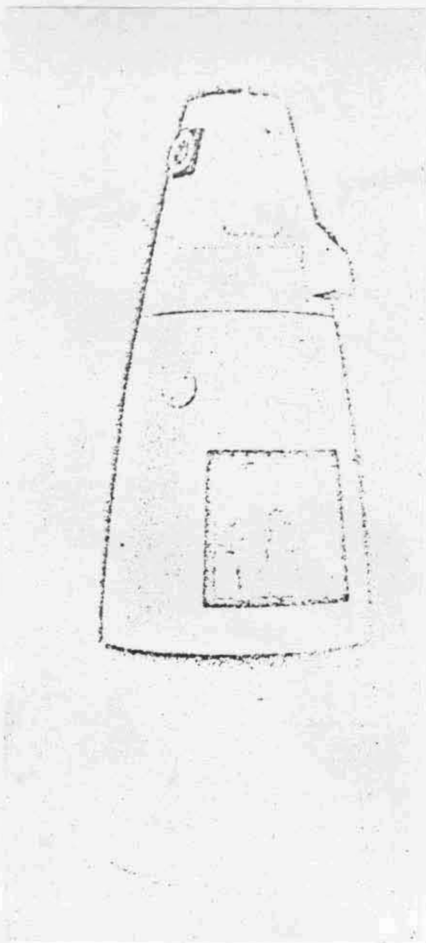
In order to establish the suitability of a cultivator for microscopic algae as a gas exchanger aboard a manned spacecraft, it was necessary first of all to determine the biological compatibility of man and algae and then to study quantitatively the gas exchange in such a closed system.

The duration of the experiments was increased from several hours to 30 days as proof was accumulated regarding the suitability of the "revitalized" atmosphere for man. The subjects were placed in a hermetically sealed chamber, connected by air lines with a cultivator for microscopic algae, which was isolated from the environment. The cabin volume was 12 m^3, and the floor area was 6 m^2.

During the experiments, no accumulation of harmful impurities to dangerous /19 levels was found in the cabin atmosphere; their concentrations in the system remained at a stable level. Obviously, the biological regeneration of the atmosphere involves not only the production of oxygen and the absorption of carbon dioxide, but also performs other hygienically important functions in improving the atmosphere.

Hence, man and microscopic algae have been found to be biologically compatible.

The experiment also demonstrated the possibility of a complete balance of gas exchange between man and microscopic algae through the selection of the appropriate nutrient medium for the algae and the choice of diet for the men.



Container with Dogs, Mounted on Class V5V Rocket.

Considerable success is being achieved in experiments in developing physico-chemical systems with closed circulation of oxygen and water. The regeneration of oxygen and water in an isolated volume and under conditions of weightlessness is an extremely complex process, and only the most reliable and effective methods are selected from the large number possible.

Currently, in conjunction with increasing the duration of flights, foreign investigators have concentrated their attention on obtaining oxygen from carbon dioxide by means of solid electrolytes. Regenerative CO_2 absorbers with an active life of up to 100 days have been proposed. Several American specialists feel that reliable and sufficiently light systems for regenerating oxygen from carbon dioxide and a water-regeneration system could be designed and installed aboard spacecraft in the 1970's. The problem of regeneration still remains a very complex one, however. The most important aspect of the design of life-support systems intended for long flights and providing for the regeneration of food, water and oxygen is the energy source aboard the spacecraft. A number of projects propose using radioisotopic energy sources with conversion of thermal energy into electrical energy.

A one-year medical and technical experiment performed in the Soviet Union at a ground testing facility to study life-support systems supports the practicality of building these systems, which will operate for long periods of time.

The facility was equipped with modern research and monitoring-measuring equipment, and included complex physico-chemical and biological-technical systems for regenerating water from urine and condensed atmospheric moisture, regeneration of oxygen from water, regeneration of water used for sanitary and domestic purposes, scrubbing the atmosphere of carbon dioxide and harmful impurities by using rechargeable absorbers, systems for utilizing carbon dioxide, growing vitamin-rich plants, etc.

On 5 September 1967, a doctor (G. A. Manovtsev), a biologist (A. N. Bozhko) and a technician (B. N. Ulybyshev) entered the hermetically sealed cabin. The latter was composed of a living area and a greenhouse, linked together. The first stage of the experiment had begun. The living area was equipped with a system for regenerating water and oxygen as well as scrubbing the atmosphere of carbon dioxide. At this stage, the greenhouse remained isolated from the living area, but was kept independently on a so-called "green conveyor" mode, which provided successive periods for harvesting fruit.

The second stage of the experiment began on 22 January 1968, when the greenhouse was connected. In the middle of this stage, a laboratory system for regenerating sanitary and domestic water to be used in washing and showering was added to the facility. /20

The final stage lasted from 5 May to 5 September 1968. The system for regenerating oxygen and absorbing carbon dioxide, based on the use of compounds containing oxygen, was disconnected. For two months, there was a changeover to new systems to provide the most complete regeneration of the atmosphere in the hermetically sealed cabin.

In accordance with the program of study, emergency situations were simulated twice: individual life-support systems were shut down or switched to another mode.

The principle of stepwise connection of individual systems to the facility that was used in the experiment proved itself completely. This made it possible to determine more exactly the role and characteristics of each system in the facility and to detect any changes in the environmental medium that

A Year Spent "Flying to the Stars While on Earth". From 5 November 1967 to 5 November 1968, at a ground facility equipped with human life-support systems under conditions of long space flights, a year-long experiment was performed involving three subjects (from top to bottom): Doctor G. A. Manovtsev, Biologist A. N. Bozhko and Technician B. N. Ulybyshev.

arose following connection of a particular system, and also made it possible to determine the characteristics of individual combinations of biotechnical systems which are characterized by different degrees of regeneration efficiency.

Problems of Space Biology and Medicine

At the present time, the most attention is being paid to a detailed study of the mechanisms of space flight operation or the reduction of its negative influence; improvement of existing closed life-support systems and design of new ones; further study of the activity of cosmonauts for the purpose of ensuring optimum methods and rates of work in carrying out specific tasks.

Despite the extreme complexity of the above problems, scientists are brimming with optimism.

Papers have already been published in which the possibility of retaining the protective functions of the cosmonaut's organism and his high level of working ability on a long flight and during spacewalks is considered.

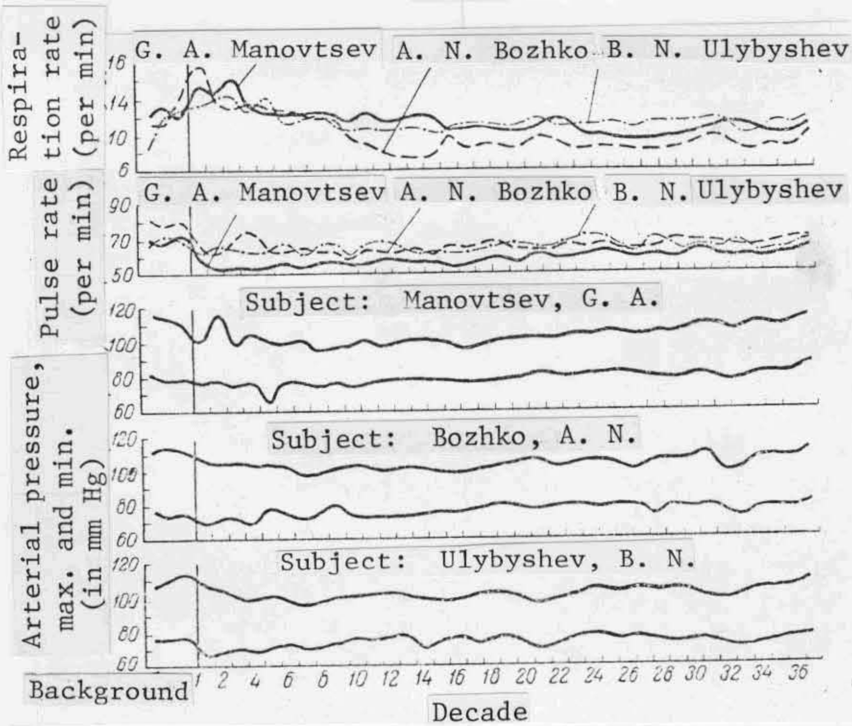
The observations conducted thus far have studied the condition of the vitally important systems of the organism - the cardiovascular and central nervous systems, and to a much lesser degree the respiratory system, as well as systems of analyzers.

/21

G. A. Manovtsev in the Living Area

There has been almost no mention of any study of the digestive and endocrine systems, or of metabolism in all of its diverse aspects.

At the present stage of development of space biology and medicine, particular attention is being devoted both to new methods of human research to allow a deeper



Graph of Changes in Physiological Functions in Subjects During the Year-Long Medico-Technical Experiment. (Caption continued on following page)

In all subjects, the majority of physiological functions changed identically. The group of subjects also was largely compatible in the psychophysiological sense. The effectiveness of the future activity of such a group will be sufficient.

understanding of the adaptability mechanisms of organisms, and also (in particular) experiments on animals with a broad comparative-physiological approach.

It will be necessary to expand considerably the biochemical and endocrinological studies of the organism of cosmonauts, in particular, to develop /22 methods of automatically collecting the required samples, automatic analysis aboard the craft, or to find reliable ways of preserving these samples for study later on Earth.

A. N. Bozhko Collects the Harvest in the "Space Greenhouse".

In addition, electron-microscope studies are of great importance: they make it possible to a large extent to support the physiological and biochemical findings.

The development of processes for synthesizing food is taking several directions, in particular the chemical synthesis of nutrient substances and the utilization of biological processes to produce proteins. Apparently the most promising of the latter processes is growing hydrogenous bacteria and yeasts on vital products of the cosmonauts.

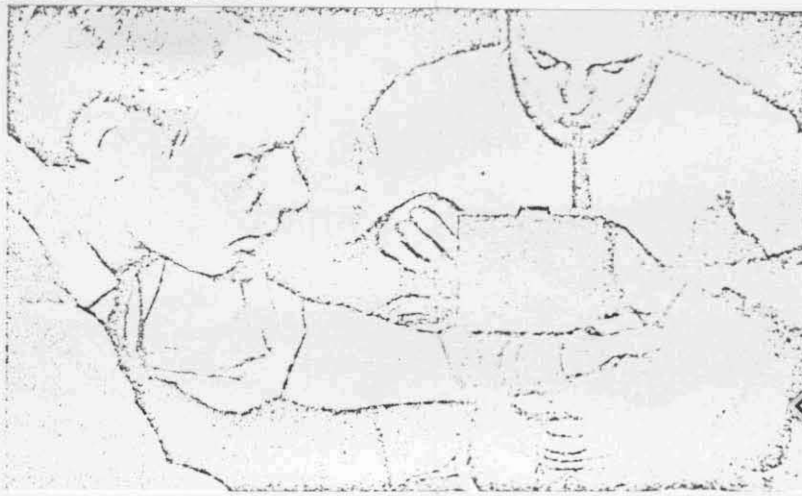
The problem of biological rhythms is of great importance for space biology. The role of the former in the retention of certain reactions of the organism under conditions of prolonged spaceflight has acquired particular significance in space physiology.

The most practical are those projects aimed at the possibility of using the results of investigating energy expenditure in movement and work under specially created terrestrial conditions, under conditions of reduced gravitation, and under the limitations involved in wearing space suits.

In order for the work to have maximum efficiency, it must be performed at a maximum rate within the limits of tolerance and skill of the individual. At low rates of movement, the energy efficiency is low, inasmuch as a considerable part of the energy is used for supporting various functions of the organism (cardiovascular, respiratory, digestive, excretory) which do not directly promote the performance of external work.

Investigation of energy expenditure in work at varying intensity involves a study of the role of individual food components in the cosmonauts' diet. It is believed that the energy balance cannot serve as a basis for judging the actual needs of the organism for the components of the food ration, inasmuch as the total balance does not reveal all those energy sources on which it is based. Thus, for example, in the course of two months diets with high and low protein content do not affect the energetic efficiency during work (however, under conditions of oxygen starvation, an insufficiency of protein in the diet will lead to a disruption of the protein composition of organisms). A relationship has been derived which makes it possible to calculate roughly the energy requirements of the organism for various gravitational conditions.

One cannot overestimate the importance of the problem of devising a single theory of biological and medical monitoring, as well as prediction in conjunction with flights of varying duration (more than a month) in space. Moreover, against the background of a generally satisfactory state of the organism, high working capacity, absence of visible deviations in the cosmonaut's behavior under specific conditions of accelerations, oxygen insufficiency or other stimuli, there may be hidden problems. It is possible to determine all the phases of the course of a reaction, against whose background the effect of some stimulus may be reinforced, inhibited or even completely attenuated by another. This is why it is necessary to exercise great caution in regard to reports of the favorable effect of individual flight factors and not their actual combination.



G. A. Manovtsev and B. N. Ulybyshev Conduct the First Test to Study Group Compatibility.

New experimental data are required which must be supplemented in labora- /23 tory conditions and aboard biosatellites. It is important to increase the depth of our knowledge not only regarding the influence on the organism of individual space flight factors (accelerations, weightlessness, hypodynamia, noise, temperature changes, etc.) but also regarding the effect of these factors in combination at all levels, beginning with the molecular and ending with the organism.

The studies of Soviet scientists enable us to conclude that the more finely the functions of an organ are controlled by the higher levels of the central nervous system, the faster and more significantly their changes will be expressed and the less time will be required to restore them to the initial level.

From the analysis of all the data obtained by various investigators in the comparative physiological plane (<u>Protozoa</u>, unicellular algae, higher plants, animals, man) considerable factual material has been gathered, a number of biological laws have been established, and new problems have arisen. In the main, these problems are extremely complex and are also interesting and fascinating. The experience gained by space biology and medicine in the first decade of its existence is a reliable prerequisite for the success of further efforts.

"Man will live and work in space." This dream of K. E. Tsiolkovskiy is becoming a reality.

The solution of many problems posed in this article will undoubtedly promote the design and launching of a space station into Earth orbit, where it will remain for a long time. A station of this kind is necessary for the comprehensive study of space. Indeed, only long-term constant observations can provide the extensive scientific data without which a knowledge of the laws of the Universe surrounding our planet is unthinkable. This is one of the advantages of a space station. Specialists in space medicine and biology will have an excellent chance to observe man in a permanent weightlessness laboratory. Permanent in the sense that man will not experience this state for a limited time, but for as long as the experiment requires. This may seem strange, but we are still a long way from knowing everything about the most important property of space, weightlessness; in fact, we know comparatively little. Aboard the orbiting space station, it will be easy to "feel" the temporal barrier of weightlessness. It is quite possible that man will not be able to hover in a state of weightlessness for an infinitely long period of time. The orbiting station will make it possible to develop and test new principles that can be used as the basis for building life-support systems aboard space stations and spacecraft. Finally, it will be possible aboard the orbiting station to study human biorhythms ... man's "biological clock." These are the principal questions which it is proposed to solve aboard the orbital stations.

The new successes of Soviet cosmonautics are giving biologists and doctors new possibilities for studying the influence of long space flights on the human organism, as well as animals and plants.